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Title: METHOD FOR PROVIDING ENHANCED PHOTOSYNTHESIS

Cross-reference to Related Applications

This application is a continuation-in-part of U.S. Patent Application No. 08/812301, filed March 5, 1997, which is incorporated herein by reference for its teachings related to the invention disclosed herein.

Field of the Invention

The present invention is directed to a method for enhancing the photosynthesis of horticultural crops.

Background of the Invention

Improved yield or plant productivity is a desired horticultural effect on horticultural crops that is generally limited by the amount of light, temperature, relative humidity and other uncontrollable environmental factors when pests, water and nutrients are adequately controlled. Particulate matter from a wide range of sources is generally regarded as limiting plant productivity. See for example, Farmer, "The Effects of Dust on Vegetation--A Review," *Environmental Pollution* 79:63-75 (1993).

The prior art has discussed photosynthesis and the effects of environmental stresses on plants. See, for example; Nonomora and Benson, "Methods and compositions for enhancing carbon fixation in plants," U.S. 5,597,400, Stanhill, G., S. Moreshet, and M. Fuchs. "Effect of Increasing Foliage and Soil Reflectivity on the Yield and Water Use Efficiency of Grain Sorghum," *Agronomy Journal* 68:329-332 (1976); Moreshet, S., Y. Cohen, and M. Fuchs. "Effect of Increasing Foliage Reflectance on Yield, Growth, and Physiological Behavior of a Dryland Cotton Crop," *Crop Science* 19:863-868

vegetables, trees, flowers, grasses, roots, seeds and landscape and ornamental plants.

The particulate materials useful for the purposes of this invention are highly reflective. As used herein, "highly reflective" means a material having a "Block Brightness" of at least about 80 and preferably at least about 90 and more preferably at least about 95 as measured by TAPPI standard T 646. Measurements can be made on a Reflectance Meter Technidyne S-4 Brightness Tester manufactured by Technidyne Corporation which is calibrated at intervals not greater than 60 days using brightness standards (paper tabs and opal glass standards) supplied by the Institute of Paper Science, or Technidyne Corporation. Typically a particle block or plaque is prepared from 12 grams of a dry (<1% free moisture) power. The sample is loosely placed in a cylinder holder and a plunger is slowly lowered over the sample to a pressure of 29.5 - 30.5 psi and held for about 5 seconds. The pressure is released and the plaque is examined for defects. A total of three plaques are prepared and three brightness values are recorded on each plaque by rotating the plaque about 120 degrees between readings. The nine values are than averaged and reported.

The finely divided particulate materials useful for the purposes of this invention may be hydrophilic or hydrophobic materials and the hydrophobic materials may be hydrophobic in and of themselves, e.g., mineral talc, or may be hydrophilic materials that are rendered hydrophobic by application of an outer coating of a suitable hydrophobic wetting agent (e.g., the particulate material has a hydrophilic core and a hydrophobic outer surface).

are particularly effective fatty acids and salts thereof for rendering a particle surface hydrophobic).

Examples of preferred particulate materials suitable for the purposes of this invention that are commercially available from Engelhard Corporation, Iselin, NJ are the calcined kaolins sold under the trademark Satintone® and the siloxane treated calcined kaolins sold under the trademark Translink®; and calcium carbonate commercially available from English China Clay under the trademarks Atomite® and Supermite® and stearic acid treated ground calcium carbonates commercially available from English China Clay under the trademarks Supercoat® and Kotamite®.

The term "finely divided" when utilized herein means that the particulate materials have a median individual particle size below about 10 microns and preferably below about 3 microns and more preferably the median particle size is about one micron or less. Particle size and particle size distribution as used herein are measured with a Micromeritics Sedigraph 5100 Particle Size Analyzer. Measurements were recorded in deionized water for hydrophilic particles. Dispersions were prepared by weighing 4 grams of dry sample into a plastic beaker adding dispersant and diluting to the 80 ml mark with deionized water. The slurries were then stirred and set in an ultrasonic bath for 290 seconds. Typically, for kaolin 0.5% tetrasodium pyrophosphate is used as a dispersant; with calcium carbonate 1.0% Calgon T is used. Typical densities for the various powders are programmed into the sedigraph , e.g., 2.58 g/ml for kaolin. The sample cells are filled with the sample slurries and the X-rays are recorded and converted to particle size distribution curves by the Stokes

have a boiling point generally no more than 100°C. These liquids enable the particulate solids to remain in finely divided form without significant agglomeration. Such low boiling organic liquids are exemplified by: alcohols such as methanol, ethanol, propanol, i-propanol, i-butanol, and the like, ketones such as acetone, methyl ethyl ketone and the like, and cyclic ethers such as ethylene oxide, propylene oxide and tetrahydrofuran. Combinations of the above-mentioned liquids can also be employed. Methanol is the preferred low boiling organic liquid.

Low boiling organic liquids may be employed in applying the particles to crop substrates for the purposes of this invention. Typically, the liquids are used in an amount sufficient to form a dispersion of the particulate material. The amount of liquid is typically up to about 30 volume percent of the dispersion, preferably from about 3 up to about 5 volume percent, and most preferably from about 3.5 to about 4.5 volume percent. The particulate material is preferably added to a low boiling organic liquid to form a slurry and then this slurry is diluted with water to form an aqueous dispersion. The resulting slurry retains the particles in finely divided form wherein most of the particles are dispersed to a particle size of less than about 10 microns.

The following examples are illustrative of embodiments of the invention and are not intended to limit the invention as encompassed by the claims forming part of the application.

EXAMPLE 1

"Red Delicious" apple trees received the following treatments: 1) Conventional pesticide applications

Treatments (1) and (3) were measured twice daily at 10 to 11 am and 2 to 3 pm. Three trees in each plot were measured with 2 sunlit leaves/tree. Canopy temperature was measured using an Everest Interscience (Model 110) infrared thermometer with +/- 0.5 °C accuracy, in which the temperature of the plant surface approximately 1 m in diameter was determined on the sunlit side of the tree. Data for canopy temperature are presented as the difference between leaf and air temperature. A negative canopy temperature denotes a canopy cooler than air temperature due to transpiration and heat reflection. The data are reported in Table I.

Table I

Treatment	Yield/tree (kg)	Fruit weight (g)	Red Color	Photosynthesis rate (μmoles $CO_2/m^2/sec$)	Stomata l conductance ($mol/m^2/sec$)	Canopy Temperature (C)
Conventional	43.7	136	19.7	6.7	0.35	-4.2
Control	30.1	123	23.2			
Translink®77	51.6	135	23.9	9.2	0.57	-5.2
Calcined Kaolin	37.6	124	21.0			
Treated CaC03	39.1	130	24.1			-5.5

The use of hydrophobic kaolin (Translink® 77) increased yield compared to conventional management (51.6 vs 43.7 kg, respectively) without a meaningful reduction in fruit size (135 vs 136 g/fruit).

The use of hydrophobic kaolin (Translink® 77) improved fruit color compared to the conventional management (23.9 vs 19.7). Treated $CaCO_3$ (SuperCoat®) and calcined Kaolin (Satintone® 5HB) also improved color compared to the conventional management (24.1 and 21.0 vs 19.7). The untreated control improved color compared to the conventional management (23.2 vs 19.7) but this is likely due to defoliation of the tree due to poor pest control since no pesticides were applied (see Lord and Greene, Ibid.). Defoliation from pest damage increases light to the fruit surface which increases color development. Pest control levels were adequate in all other treatments and did not result in defoliation.

Average precipitation approximates 35.6 cm from April 1 to August 30; precipitation was 40% below normal.

basis to meet plant water needs using sprinkler irrigation located beneath the trees. Photosynthesis and stomatal conductance were measured on July 17 to 20, 1997. Photosynthesis data were collected using a Licor 6300 photosynthesis system. Treatments (1) , (2) and (3) were measured twice daily at 10 to 11 am and 2 to 3 pm. Three trees in each plot were measured with 2 sunlight leaves/tree. Data are the mean values for all days and hours sampled. Canopy temperature was measured using an Everest Interscience Infrared (Model 110) thermometer with +/- 0.5 C accuracy, in which the temperature of the plant surface approximately 1 meter in diameter was determined on the sunlit side of the tree. Data for canopy temperature are presented as the difference between leaf and air temperature. A negative canopy temperature denotes a canopy cooler than air temperature due to transpiration and heat reflection. Canopy temperature data were collected from Aug 17 to 20, 1997. The data presented in Table IV are representative of the entire data set. At the time of harvest, 20 fruit were randomly collected from each of the 3 trees/plot (total of 180 fruit/treatment). Fruit were weighed and color determined. Color was determined with a Hunter colorimeter. Color values represent Hunter "a" values.

Table II

Treatment	Fruit weight (g/fruit)	Photosynthesis (μmol $CO_2/m^2/sec$)	Stomatal conduct- ance ($mol/m^2/sec$)	Canopy temperature (°C)
Control	164	8.8	0.24	-4.5
Translink® 77 applied 7 times	177	11.8	0.43	-5.7

Translink® 77 applied 10 times	195	12.9	0.46	-6.0

Fruit size increased with increasing applications of Translink® 77.

Trees in the study had fruit size greater than the study in Kearneysville, WV due to the use of irrigation.

The reduced canopy temperature of both Translink® 77 treatments illustrates that the application of these particles can reduce plant temperature.

The application of Translink® 77 increased photosynthesis, stomatal conductance and reduced plant temperature. Canopy temperature was reduced by the application of Translink® 77 due to the increased transpirational cooling of the leaf related to increased stomatal conductance resulting from the application of Translink® 77. Reducing the frequency of application from 7 applications did reduce photosynthesis, stomatal conductance, and canopy temperature compared to 10 applications, demonstrating that there is a beneficial response to increasing amounts of Translink® 77 coverage.

Example 3

Santiago, Chile

"September Lady" peach, spaced 4m x 6m, received the following treatments: 1) Conventional pesticide application applied according to the presence of economic levels of pests, 2) no treatment, 3) weekly application of Translink® 77 beginning October 29, 1996. Treatment (3) applied 25 pounds material suspended in 4 gal methanol and added to 96 gal water. This mixture was applied at the rate of 100 gal/acre using a high

block design. At harvest the plots were commercially harvested and processed by a commercial grading line. At the time of grading, 100 fruit from each plot were randomly chosen to determine fruit size, color, and surface defects. Color was determined using a Hunter colorimeter. Green color values represent Hunter "a" values in which higher values represent more yellow color, a beneficial trait in "Golden Delicious" apple. The data are reported in Table IV.

Table IV

Treatment	Fruit size (mm)	Green color
Translink® 77 full rate	69	-8.0
Translink® 77 half rate	67	-8.9
Conventional	67	-10.0

Application of Translink® 77 at the full and half rate reduced green color, and Translink® 77 at the full rate increased fruit size compared to the half rate and conventional treatment.

"Stayman" apples received 2 treatments: 1) commercial pesticide application applied according to the presence of economic levels of pests using the Virginia, West Virginia and Maryland Cooperative Extension 1997 Spray Bulletin for Commercial tree Fruit Growers publication 456-419, 2) Translink® 77 treatment applied 25 pounds material suspended in 4 gal methanol and added to 96 gal water. This mixture was applied at the rate of 200 gal/acre using an orchard sprayer. Each treatment was applied to 1 acre blocks with no randomization. Apples were harvested commercially and processed on a commercial grading line. Data presented represent percent packout from the commercial grading line. The data are reported in Table V.

Table V

Treatment	Fruit size (mm)	<2.5 inches (%)	2.5 - 2.75 inches (%)	2.75 - 3.0 inches (%)	> 3.0 inches (%)
Translink® 77	69	11	38	44	7
Conventional	62	66	28	6	0

The application of Translink® 77 increased the packout of larger fruit and reduced the losses due to small fruit (<2.5 inches) compared to the conventional treatment.